**Comments of**

**American Farm Bureau Federation**
**American Forest and Paper Association**
**American Highway Users Alliance**
**American Iron and Steel Institute**
**American Petroleum Institute**
**Chamber of Shipping of America**
**Global Climate Coalition**
**National Association of Manufacturers**
**National Lime Association**
**National Mining Association**
**National Ocean Industries Association**
**National Petrochemical and Refiners Association**
**Steel Manufacturers Association**
**The Fertilizer Institute**
**United States Chamber of Commerce**

**to**

**Office of the U.S. Global Change Research Program**

**Draft Report**
***Climate Change Impacts on the United States:***
***The Potential Consequences of Climate Variability and Change***

**65 Fed.Reg. 36845 (June 12, 2000)**

**August 11, 2000**

August 8, 2000

National Assessment Comments
Office of the U.S. Global Change Research Program
400 Virginia Ave., SW
Suite 750
Washington, D.C. 20024

Dear Sir or Madam:

The trade associations listed on the cover of the attached comments have authorized me to file them on their behalf.

Many of these groups, including the Global Climate Coalition, have requested extensions in the short sixty-day comment period that severely constrained our ability to respond in a comprehensive and thorough fashion to the nearly 1000 pages of the draft National Assessment Overview and Synthesis Reports. Aside from the limited time provided for public comment, the absence of key graphs and charts, and the fact that several of the underlying regional and sectoral reports have not yet been completed or made publicly available further served to hamper our ability to respond.

The regional focus of the draft Reports, based on climate modeling, was not a stated requirement of the Global Change Research Act of 1990 that authorized the National Assessment. In the addition, the Reports' exclusive reliance on two contradictory models renders it incapable of serving the planning and informational needs of the audiences for which it was ostensibly prepared, most especially the United States Congress and the Executive Office of the President.

The references addressed in the comments make clear that the scientific community for the past decade has noted with resounding consensus that climate models are incapable of providing any meaningful predictive information as to future regional impacts of climate change. By exclusively relying on the Canadian and Hadley Centre models – two models that repeatedly contradict one another on precipitation, temperature, soil moisture and more – the National Assessment process has apparently not recognized the substantial predictive limitations inherent among these valuable but underdeveloped tools. EPA's own web site, for example, contains the following statement:

> "Scientists are unable to say whether particular regions will receive more or less rainfall; and for many reasons they are unable to even state whether a wetter or drier climate is more likely…. Virtually all published estimates of

> how climate could change in the United States are the results of computer models known as 'general circulation models.' These complicated models are able to simulate many features of the climate, but are still not yet accurate enough to provide reliable forecasts of how the climate may change; and several models often yield contradictory results…"

Finally, the National Assessment's insufficient consideration of future socioeconomic conditions, an essential element in any analyses of future climate impacts, represents yet another major shortcoming of the draft Reports.

These thematic comments address factors that speak to the overall inability of the draft Reports to serve their authorized purpose. Instead, the draft Reports appear designed to tell detailed stories about future regional climate impacts even though the best experts tell us "…even the best models today can say little that's reliable about climate change at the regional level…." (*Science* June 23, 2000).

The attached comments alone are submitted on behalf of the trade associations named on the cover page of the comments. Should you have any questions regarding these comments or any other matter, please feel free to contact me at (202) 682-9161.

Sincerely,

Glenn Kelly
Executive Director

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## Table of Contents

# 1. Regional Impacts Can Not be Reliably Predicted

Perhaps the single most important flaw in the current U.S. National Assessment is its premise – that current climate knowledge and climate models can generate meaningful estimates of regional climate change impacts. At the inception of the current National Assessment effort, there was a broad consensus that remains true today that however good or bad the predictive ability of global climate models, that predictive ability did not extend to regional climate impact assessments. Yes, the computer models can generate results for Chicago or any other location, and they can do so for a seemingly infinite number of scenarios. But if computer models cannot generate consistent estimates of regional impacts, even in those limited instances when global models provide similar scenarios for *global* climate change, then *regional* impact numbers are simply not meaningful -- for a Congressional policy assessment or otherwise.

This National Assessment is the first such effort undertaken under the U.S. Global Change Research Act of 1990 (P.L. 101-606). That Act, which called for a "scientific assessment" "not less frequently than every four years", <u>does not require or even suggest a *regional* assessment</u>. What the Act specified was an assessment that:

- integrates, evaluates, and interprets the findings of the Program and discusses the scientific uncertainties associated with such findings;
- analyzes the effects of *GLOBAL CHANGE* on the natural environment, agriculture, energy production and use, land and water resources, transportation, human health and welfare, human social systems, and biological diversity; and
- analyzes current trends in *GLOBAL CHANGE*, both human-induced and natural, and projects major trends for the subsequent 25 to 100 years. [1]

Nevertheless, the US Global Change Research Program (USGCRP) chose to undertake a US *regional* impact effort, despite a broad and widely accepted conclusion that credible regional climate analysis simply was not yet viable. As illustrated below, this view is widely held even today. As *Science* clearly stated in its June 23, 2000 issue, "Even the best models today can say little that's reliable about climate change at the regional level…."

### *a. Views on Regional Modeling in 1995-1998*

In the Second Assessment of climate science by the Intergovernmental Panel on Climate Change (IPCC), it was concluded that confidence in regional climate projections "remains low." If fact, problems were so severe that the IPCC decided that "no information on future regional climate change" should be presented in the Summary for Policymakers. According to the IPCC Working Group I to the Second Assessment: *Report of the Intergovernmental Panel on Climate Change, Summary for Policymakers* (approved in November 1995):

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[1] U.S. Global Change Research Program Act of 1990, Public Law 101-606(11/16/90) 104 Stat. 3096-3104, Section 106.

> Page 41: “Confidence is higher in the continental scale projections of climate change than at regional scales, where confidence remains low.”
>
> Page 43: “ In general, regional projections are also sensitive to model resolution and are affected by large natural variability. Hence, confidence in regional projections remains low.”
>
> Page 43-4: “Estimation of the potential impacts of climate change on human infrastructure and natural ecosystems requires projections of future climate changes at the regional scale, rather than as global or continental means. Since IPCC (1990), a greater appreciation has been developed of the uncertainties in making projections at the regional scale. There are several difficulties: The global models used for future projections are run at fairly coarse resolution and do not adequately depict many geographic features (such as coastlines, lakes and mountains), surface vegetation, and the interactions between the atmosphere with the surface which become more important on regional scales…. Because of these problems, no information on future regional climate change is presented here.”
>
> Page 46: “An important long-term goal is the accurate projection of regional climate change, so that potential impacts can be adequately assessed. Progress towards this objective depends on determining the likely global magnitude and rate of human-induced climate change, as well as the regional expressions of these quantities.”

These concerns were also evident at more technical levels within the IPCC effort. According to the IPCC’s Working Group II to the Second Assessment: *Climate Change 1995 – Impacts, Adaptation and Mitigation of Climate Change: Scientific-Technical Analyses,* Cambridge University Press (1996):

> Page 24: “Impacts are difficult to quantify, and existing studies are limited in scope. While our knowledge has increased significantly during the last decade and qualitative estimates can be developed, quantitative projections of the impacts of climate change on any particular system at any particular location are difficult because regional scale climate change projections are uncertain; our current understanding of many critical processes is limited; and systems are subject to multiple climatic and non-climatic stresses, the interactions of which are not always linear or additive.”

The IPCC even commissioned a Special Report on regional impacts of climate change that was published in 1998. This report by IPCC Working Group II (*The Regional Impacts of Climate Change, An Assessment of Vulnerability -- A Special Report of IPCC Working Group II*) included the following conclusions:

> Preface: “Because of the uncertainties associated with regional projections of climate change, the report necessarily takes the approach of assessing sensitivities and

vulnerabilities of each region rather than attempting to provide quantitative predictions of the impacts of climate change."

Page 4: "In a number of instances, quantitative estimates of impacts of climate change are cited in the report…. To interpret these estimates, it is important to bear in mind that uncertainties regarding the character, magnitude, and rates of future climate change remain. These uncertainties impose limitations on the ability of scientists to project impacts of climate change, particularly at regional and smaller scales."

Page 22: "Because the available studies have not employed a common set of climate scenarios, and because of uncertainties regarding the sensitivity and adaptability of natural and social systems, the assessment of regional vulnerabilities is necessarily qualitative. Often only very general conclusions can be supported by the currently available evidence."

Others, from both the private sector and the U.S. government research communities, were more direct about the ability to do meaningful regional climate analysis.

Dr. Brent Yarnal, a Pennsylvania State University scientist, told a February 26, 1998 EPA Climate Change Conference in Philadelphia that:

" 'I'd be a liar if I said we are certain of everything' on what global warming might hold for the mid-Atlantic states. 'Our knowledge of what's going to happen on a regional basis is extremely poor,' the climatologist told about 150 people at the conference." (*Richmond Times Dispatch* – February 28, 1998).

Dr. J.D. Mahlman, Director of the Geophysical Fluid Dynamics Laboratory, National Oceanographic and Atmospheric Administration, Princeton University, is quoted in an article on "Uncertainties in Projections of Human-Caused Climate Warming," (*Science*, November 21, 1997) as stating that*:*

*"There are a number of statements in informal* writings that are not supported by climate science or projections with high-quality climate models…. **There is a large demand for specific climate change predictions at the regional and local scales where life and life support systems are actually affected. Unfortunately, our confidence in predictions on these smaller scales will likely remain relatively low.** Much greater fidelity of calculated local climate impacts will require large improvements in computational power and in the physical and biological sophistication of the models. For example, the large uncertainty in modeling the all-important responses of clouds could become even harder at regional and local levels. Major sustained efforts will be required to reduce these uncertainties substantially…. [T]he remaining uncertainties in modeling important aspects of the problem make it evident that we cannot yet produce a sharp picture of how the warmed climate will proceed, either globally or locally…. The severity of impacts can be modest or large, depending on how some of the remaining key uncertainties are resolved through eventual changes in the real climate system…."

And according to Eric J. Barron in “Climate Models: How Reliable Are Their Predictions?” (*CONSEQUENCES*, November 3, 1995):

> Page 8: “We have only a very limited capability to estimate changes expected in the climate of any specific region. The spatial resolution of climate models is, as yet, too coarse to incorporate effects such as regional land characteristics, surface contours, and local hydrologic conditions, even though these factors are known to be important. Regional changes in climate can differ from global changes, but the nature of the probable differences is uncertain.”

> Page 12: “…the level of confidence in the results from present climate models depends very much on the spatial and temporal specificity of the prediction. The most certain are those that pertain to the Earth as a whole and that apply to a roughly fifty-year period. Regional predictions, predictions on a decade-by-decade basis, and predictions of higher-resolution phenomena such as hurricanes, are considerably less certain. For the decisions that we face as individuals, it would be much better were it otherwise…”

### *b. Current Views on the Credibility of Regional Modeling*

Studies by the Pew Center on Global Climate Change include information on current abilities to assess regional climate change. One indication of the state of assessment was contained in a Pew study on *Water and Global Climate Change*. This study looked closely at the two models used in the U.S. National Assessment and concluded, for example, that one of the models raised concerns about flooding while the other raised concerns about water scarcity.

According to the Pew Center *Study on Water and Global Climate Change, Executive Summary*, released September 29, 1999:

> Page 1: “Global climatic changes will have major effects on precipitation, evapotranspiration, and runoff. But estimating the nature, timing, and even the direction of the impacts at the regional and local scales of primary interest to water planners involves many uncertainties."

> Page 4: “The ongoing National Assessment of the impacts of climate change on the Untied States is evaluating the implications of two different models – the Hadley and Canadian GCMs (General Circulation Models). Estimates of the impacts of climate change on runoff within the water resource basins and subbasins in the coterminous United States using the outputs of these two general circulation models show similarities and sharp differences…. Estimates based on the Hadley model indicate flooding could increase in much of the country, while those based on the Canadian climate model indicate increased water scarcity would pervade much of the country…. Results based on these GCM outputs as well as more detailed regional studies emphasize two points: the detailed regional impacts of a greenhouse warming on future water supplies are uncertain and runoff is sensitive to changes in temperature and precipitation.”

A second Pew study, by noted climate scientists Tom Wigley, also concluded that there are major unresolved uncertainties in attempting to assess potential regional climate impacts. According to Dr. Wigley, in *The Science of Climate Change, Global and US Perspectives,* published by the Pew Center on Global Climate Change, (June 1999):

> Page 1: "Future regional-scale precipitation changes are highly uncertain."
>
> Page 22: "To assess the importance of these [global-mean] changes to the United States and to plan adaptive strategies to minimize potential damages, we need to have information about the spatial details of climate change and their associated uncertainties. This information can be obtained only by using computationally-demanding GCMs [general circulation models] of the climate system; and even here, the spatial resolution of such models is quite coarse – 200 km at best."
>
> Page 23: "How credible are the currently available GCMs? There are two ways to answer this question. The first is a standard model evaluation procedure: one simply compares the model's simulation of current climate with observations. Analyses like these give widely varying results… A second approach is to compare the results of different models when they are all used to perform the same type of climate-change experiment. For the present analysis, results of 15 different models are compared…."
>
> Page 32: "The large inter-model differences in projections of mean precipitation change…imply that one should treat the predictions of single models cautiously, especially for changes in the shorter time-scale events…."
>
> Page 35: "Future regional-scale precipitation changes are highly uncertain. The only result that is common to all climate models is an increase in winter precipitation in northern latitudes.…"
>
> Page 48: "[W]hile we may even now be able to identify the human component of global-mean temperature change above the noise of natural variability, we cannot yet confidently identify the human component on small (sub-continental) scales."

Some of the problems with attempts at regional modeling relate to the sheer complexity of the factors involved. One scientist, Roger Pielke of Colorado State University, pointed out some of this complexity. In a presentation before the American Meteorological Society ("Overlooked Issues in the U.S. National Climate and IPCC Assessments," American Meteorological Society, 11th Symposium on Global Change, Long Beach, California, January 2000), Dr. Pielke observed that:

> Page 32: "Human-caused landuse change has an effect on local, regional, and global climate that is at least as large as could be caused by doubling of greenhouse gases…Since landscape (and other atmosphere-surface interactions) involve complex nonlinear feedbacks, skillful climate prediction beyond seasonal time scales may be unachievable."

> Page 34: "Unless it can be shown that landuse change and biogeochemical effects on the regional and global climate system are insignificant relative to the radiative effect of a doubling of CO2, the IPCC reports are summaries of sensitivity analyses only. It is, therefore, unlikely that the future climate is actually produced using these models."

Others raise key issues with the underlying global climate models that are the starting point for regional climate change impact assessment. According to Dr. Freeman J. Dyson (Institute for Advanced Study, Princeton University) in a talk given at an American Physical Society Centennial meeting Atlanta, Georgia, March 25, 1999 ("The Science and Politics of Climate"):

> Page 4: "There is good news and bad news. The good news is that we are at last putting serious effort and serious money into local observations. Local observations are laborious and slow, but they are essential if we are ever to have an accurate picture of climate. The bad news is that the climate models on which so much effort is expended are unreliable. The models are unreliable because they still use fudge-factors rather than physics to represent processes occurring on scales smaller than the grid-size."
>
> "Besides the general prevalence of fudge-factors, the climate models have other more specific defects that make them unreliable. First, with one exception, they do not predict the existence of El Nino. Since El Nino is a major and important feature of the observed climate, any model that fails to predict it is clearly deficient. Second, the models fail to predict the marine stratus clouds that often cover large areas of ocean. Marine stratus clouds have a large effect on climate in the oceans and in coastal regions on their eastern margins. Third, the climate models do not take into account the anomalous absorption of radiation revealed by Atmospheric Radiation Measurements (ARM). This is no small error. If the ARM measurements are correct, the error in the atmospheric absorption of sunlight calculated by the climate models is about 28 watts per square meter, averaged over the whole earth, day and night, summer and winter. The entire effect of doubling the present abundance of carbon dioxide is calculated to be about 4 watts per square meter. So the error in the models is much larger than the global warming effect that the models are supposed to predict."
>
> "Until the fudge-factors are eliminated and the computer programs are solidly based on local observations and on the law of physics, we have no good reason to believe the predictions of the models."
>
> "Climate models are still, as Manabe said, essential tools for understanding climate. They are not yet adequate tools for predicting climate…Until then, we must continue to warn the politicians and the public, don't believe the numbers just because they come out of a supercomputer."

The inability to do meaningful regional climate assessment was even acknowledged *within* the U.S. National Assessment program. The Health Section of the U.S. National Assessment published its Executive Summary in *Environmental Health Perspectives*, Volume 108, Number 4, April 2000. This summary, titled "The Potential Health Impacts of Climate Variability and

Change for the United States: Executive Summary of the Report of the Health Sector of the U.S. National Assessment", stated that:

> "Projections of the extent and direction of some potential health impacts of climate variability and change can be made, but there are many layers of uncertainty. First, methods to project changes in climate over time continue to improve, but climate models are unable to accurately project regional-scale impacts."

And finally, it is critical to note that the research center that created one of the models used in the U.S. National Assessment forcefully stated that the "agreement between regional predictions from global models is poor." Without agreement on regional prediction, even within global models that have similar outcomes in global simulations, there is simply no rational basis for attempting to evaluate regional climate change, especially as input into policymakers.

According to the Hadley Centre report, "Regional Climate Predictions for National Vulnerability Assessments," presented at the UN Framework Convention on Climate Change, 12th meeting of the Subsidiary Bodies, June 2000:

> "Global climate models (GCM) can provide scenarios of changes in climate down to scales of 1000km or so at best. Where the terrain is reasonably flat and uniform, and away from coasts, these scenarios may be adequate, given the inherent uncertainties in all model predictions. But in areas where coasts and mountains have a significant effect on weather (and this will be true for most parts of the world), scenarios based on global models will fail to capture the regional detail needed for vulnerability assessments at a national level."
>
> "RCMs [Regional Climate Models] do not replace or supercede GCMs; indeed they give added impetus to the development of GCMs. The agreement between regional predictions from global models is poor; hence improved regional prediction will only be achieved if global model performance is improved in parallel."

This assessment by the Hadley Centre was reinforced by *Science*, which concluded that "Even the best models today can say little that's reliable about climate change at the regional level…." In an extended commentary on the models used in the U.S. National Assessment to generate region results, *Science* ("Dueling Models: Future U.S. Climate Uncertain", *Science,* Vol. 288, June 23, 2000) made the following comments.

> "The [U.S. National Assessment] report, which divides the country into eight regions, is based on a part of state-of-the-art climate models –one from the Canadian Climate Center and one from the U.K. Hadley Center for Climate Research and Prediction—that couple a simulated atmosphere and ocean. The two models solved the problems of simplifying a complex world in different ways, leading to very different predicted U.S. climates."
>
> "Even given more time and money, however, the assessment may not have come up with much better small-scale predictions, given the inherent limitations of the science. Even

> the best models today can say little that's reliable about climate change at the regional level, never mind at the scale of a congressional district."
>
> "[Filippo] Giorgi and his colleague Raquel Francisco of the Abdus Salam International Center for Theoretical Physics in Trieste, Italy, recently evaluated the uncertainties in five coupled climate models—including the two used in the national assessment—within 23 regions, the continental United States comprising roughly three regions. Giorgi concludes that as the scale of prediction shrinks, reliability drops until for small regions 'the model data are not believable at all.'"

When Congress established the requirement for a periodic scientific assessment of climate change in 1990, it did not mandate or suggest that the U.S. National Assessment be a regional assessment. Given the known inability of climate science and climate models to generate meaningful regional climate assessments, both when the current U.S. National Assessment effort was initiated and today, the current effort is necessarily and unfortunately as flawed as its fundamental premise. As *Science* clearly stated in its June 23, 2000 edition, "Even the best models today can say little that's reliable about climate change at the regional level…."

## 2. Canadian and Hadley Centre Models Give Contradictory Regional Results

Given the flawed fundamental premise of the National Assessment effort, it should be no surprise that the basic model inputs into the process were contradictory. The U.S. National Assessment used one simulation from each of two global climate models, the Canadian model and the Hadley Centre model, as the central basis of assessing regional climate change. Comparing the results of these two simulations illustrates extremely well the conclusion of the Hadley Centre as presented to the UN Framework Convention on Climate Change, 12th meeting of the Subsidiary Bodies, June 2000. According to the Hadley Centre:

> "The agreement between regional predictions from global models is poor; hence improved regional prediction will only be achieved if global model performance is improved in parallel." [2]

The following three sets of figures drawn directly from the National Assessment web site[3] clearly illustrate the divergent results from the two climate models that so concerned the Hadley Centre. On the key measures of temperature, precipitation and soil moisture, the Canadian and Hadley Centre models provide widely divergent indications of potential future climate change. As a result, the models also give widely conflicting indications of potential future regional climate change and impacts.

Following the figures are tables drawn from Technical Review descriptions and comparisons of the Canadian and Hadley Centre model outputs. Since the climate models have not been changed since the technical review, the model results still hold. As with the output for temperature, precipitation and soil moisture, these conflicting outputs clearly reflect the state of climate modeling documented earlier. Simply put, meaningful regional modeling suitable for use by policymakers is simply not available.

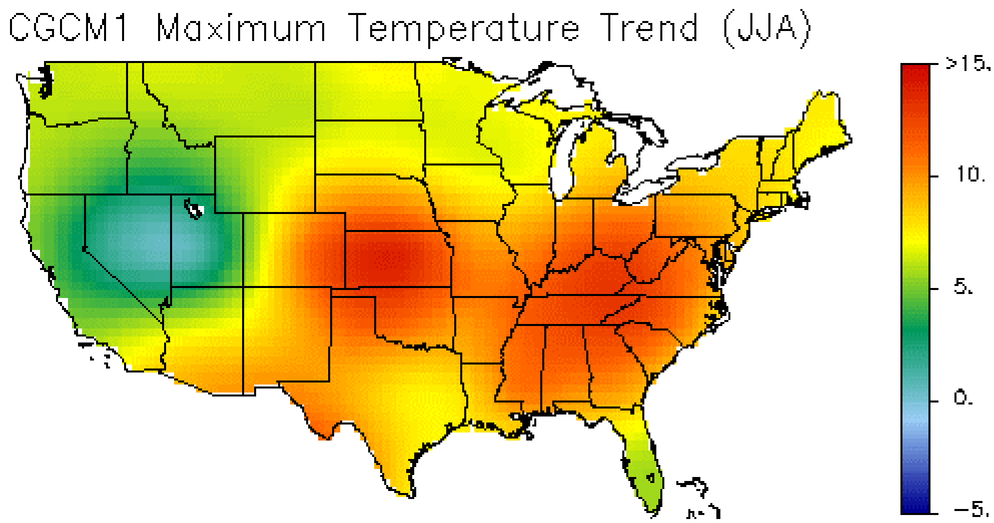
| |
|---|
| Note: The contradictions between the Canadian and Hadley models are seen clearly in color. See Internet address below for the original source for the following figures. |

[2] "Regional Climate Predictions for National Vulnerability Assessments" by the Hadley Center for Climate Prediction and Research, presented at the UN Framework Convention on Climate Change, 12th meeting of the Subsidiary Bodies, June 2000.

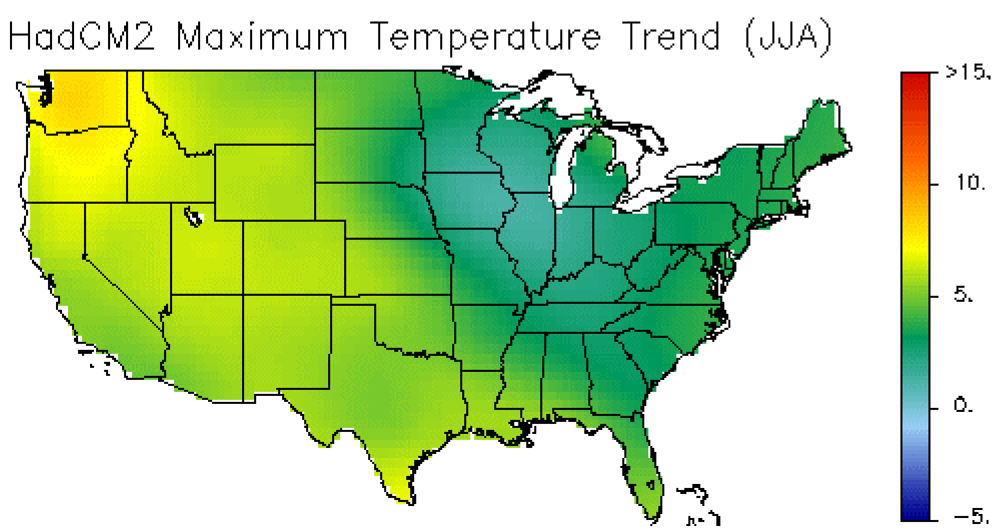
[3] Source: U.S. National Assessment internet site: www.cgd.ucar.edu/naco/vemap/trends.html

***a. National Assessment Models Conflict on Temperature***

## ***Canadian Model - Hot***



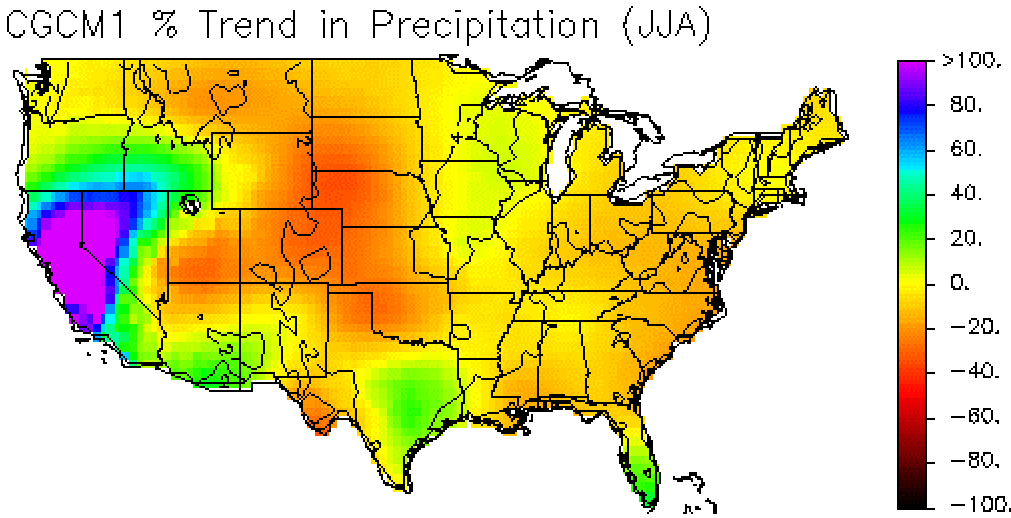

## ***Hadley Centre Model - Cool***



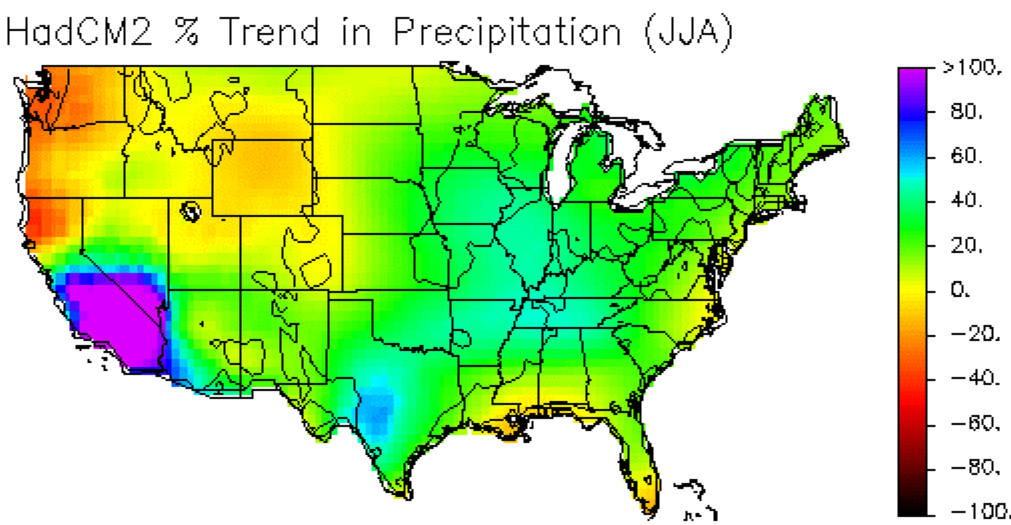

Source: U.S. National Assessment – www.cgd.ucar.edu/naco/vemap/trends.html

***b. National Assessment Models Conflict on Precipitation***

## ***Canadian Model - Dry***



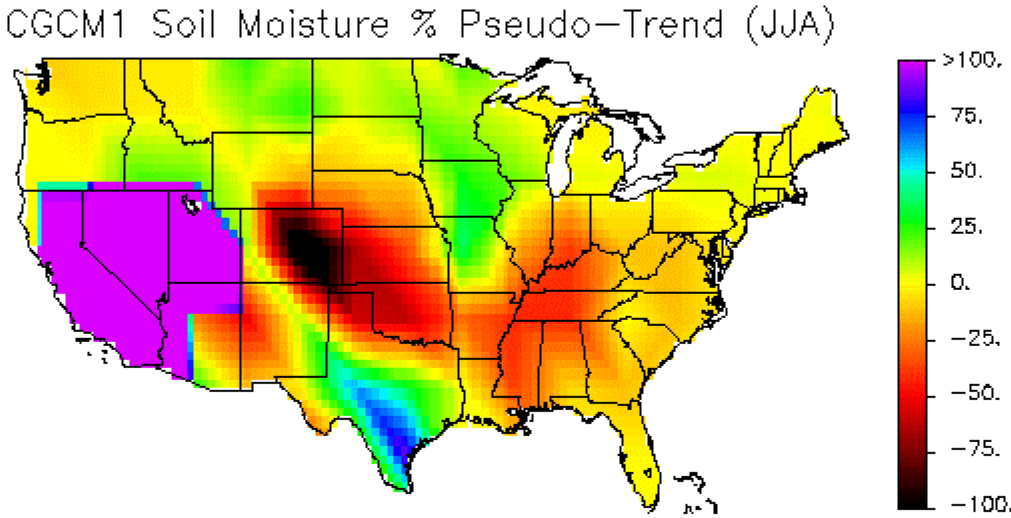

## ***Hadley Centre Model – Wet***



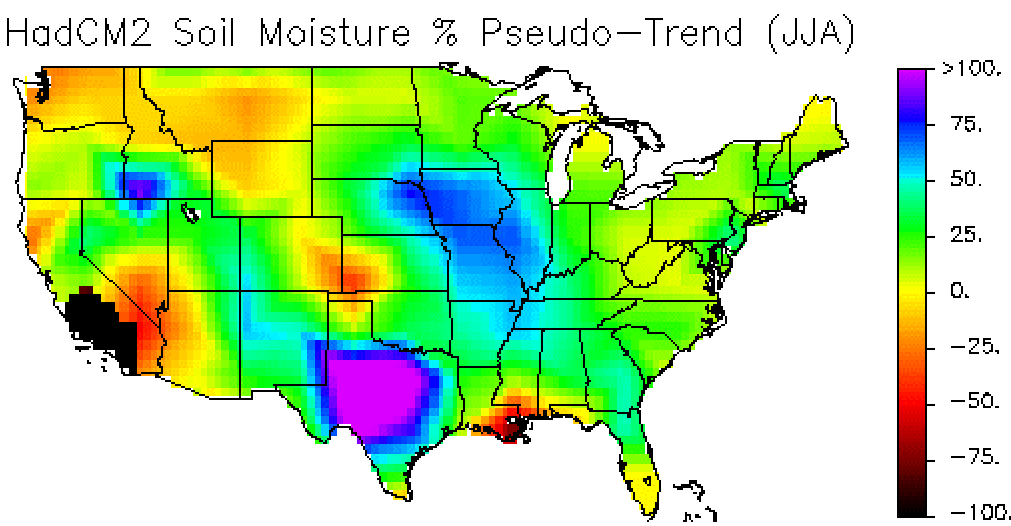

Source: U.S. National Assessment – www.cgd.ucar.edu/naco/vemap/trends.html

***c. National Assessment Models Conflict on Soil Moisture***

## ***Canadian Model - Dry***




## ***Hadley Centre Model – Wet***




Source: U.S. National Assessment – www.cgd.ucar.edu/naco/vemap/trends.html

### *d. Northeast – Model Contradictions*

**(Maine, New Hampshire, Vermont, Massachusetts, Connecticut, Rhode Island, New York, New Jersey, Delaware, Maryland, Pennsylvania, West Virginia)**

| Canadian Model | Hadley Model |
|---|---|
| ***Climate Change*** | |
| ↑ 9 $^{o}$F mean temperature increase by 2100<br>↓ Little change in precipitation or decreases approaching 5% to 10%<br>↓ Decreased storm counts<br>↑ Tendencies for severe drought to increase<br>↓ Small decrease in variability of temperature | ↑ 6$^{o}$F mean temperature increase by 2100<br>↑ Precipitation increases 8% by 2030 and 24% by 2100<br>↑ Increased and stronger storms<br>↓ Less drought tendencies<br>↓ Small decrease in variability of temperature |
| ***Agriculture*** | |
| ↑ Agriculture is relatively robust to climate change even though the crop mix may change. | |
| ***Water*** | |
| ↓ 4% decrease in runoff for the Susquehanna River Basin<br>↑ 3% or less change in salinity of the Chesapeake | ↑ 24% increase in runoff in the Susquehanna River Basin<br>↓ 20% decrease in salinity within northern segment of Chesapeake, and as much as 4% change in southern segment of the Bay |
| ***Forests*** | |
| ↑ Substantial changes.<br>Conifer forest of New England and mixed forest of New England, New York and western Pennsylvania change to temperate deciduous. Area of southeast mixed forest becomes compressed. | ↓ Less dramatic changes.<br>Conifer forest of new England replaced by northeast mixed. Area of deciduous forest of New England, Pennsylvania and West Virginia grows slightly. Southeast mixed forest grows in Virginia. |

### *e. Southeast – Model Contradictions*

**(Kentucky, Tennessee, Virginia, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Arkansas, Louisiana)**

| ***Canadian Model*** | ***Hadley Model*** |
|---|---|
| ***Climate Change*** | |
| ↑ Mean annual temperature increase of 3°F by 2030 and 10°F by 2100<br>↓ Less precipitation than present<br>↓ Decreased soil moisture | ↑ Mean annual temperature increase of 1.8°F by 2030 and 4.1°F by 2100<br>↑ More precipitation than present<br>↑ Increased soil moisture |
| ***Agriculture*** | |
| ↓ The decrease in precipitation indicated by Canadian model would cause major reductions in crop yields. | ↑ Irrigation needs will decline in some areas and crop production could be enhanced in most areas. |
| ***Water*** | |
| ↓ Little change until 2030, then drier weather over next 70 years. | ↓ Slight decrease in precipitation over next 30 years, followed by change in precipitation pattern (decreased precipitation during first 6 months of year followed by return to normal for last 6 months). |
| ***Forests*** | |
| ↑ 33% increase in forest productivity<br>Pattern of decline in pine growth and replacement with hardwood is accentuated with higher temperatures. | ↑ 46% increase in forest productivity<br>In 2030 southern pine and hardwood forest types would be equally productive. By 2090 hardwoods would be approximately 27% more productive than pine forests. |

### *f. Midwest – Model Contradictions*
### (Minnesota, Wisconsin, Michigan, Iowa, Missouri, Illinois, Indiana, Ohio)

| ***Canadian Model*** | ***Hadley Model*** |
|---|---|
| ***Climate Change*** | |
| ↑ Mean annual temperature warms by 10°F by 2100<br>↑ Frequency and intensity of droughts increase<br>↓ Reduced soil moisture content<br>↓ Decrease in snow cover season | ↑ Mean annual temperature warms by 5°F by 2100<br>↓ Frequency and intensity of droughts decrease<br>↑ Increased soil moisture content<br>↓ Decrease in snow cover season |
| ***Agriculture*** | |
| ↑ Under climate change scenarios, a longer growing season would likely translate into increased farm production.<br>↑ Even non-irrigated crops are likely to increase yields with an increased growing season.<br>↑ CO2 fertilization by itself may enhance crop production. | |
| ***Water*** | |
| ↓ Reduced levels of Great Lakes by up to 5 feet.<br>↓ Reduction in mean annual outflow from each lake of 20% to 30% by 2090.<br>↑ Water surface temperature increase between 4.5° F and 9° F.<br>↓ Ice cover duration for Lakes Superior & Erie show decreases of up to 65 days | ↑ Increase in Great Lake levels by less than 1 foot.<br>↑ Increase in annual outflow from each lake of between 2% and 7%.<br>↑ Water surface temperature increase 4.5° F and 9° F.<br>↓ Ice cover duration for Lakes Superior and Erie show decreases of 29 days. |
| ***Forests*** | |
| ↓ Increased potential for more drought and excessive wet periods, increasing forest fire potential and making current forestlands more susceptible to pests and diseases. | ↑ Higher temperatures coupled with beneficial effects of increased CO2 could lead to an increase in tree growth rates on marginal forestlands that are currently temperature limited. |

***g. Great Plains – Model Contradictions***

**(Montana, North Dakota, Wyoming, South Dakota, Colorado, Nebraska, Kansas, Oklahoma, New Mexico, Texas)**

| ***Canadian Model*** | ***Hadley Model*** |
|---|---|
| ***Climate Change*** | |
| ↑ Mean annual temperature warms by 12$^o$F by 2100<br>↓ Decrease in precipitation in southern Plains states and increases in northern Plains | ↑ Mean annual temperature warms by 5$^o$F by 2100<br>↑ Increase in precipitation over much of the entire region |
| ***Agriculture*** | |
| ↓ ↑Climate change is projected to increase production in fertile areas, putting marginal areas at a further disadvantage. Increased production will lower prices for consumers in general, but will increase the stress on farmers and rural communities in this region. | |
| ***Water*** | |
| ↑ Increases in temperature and droughts. | |
| ***Forests*** | |
| Not applicable | |
| Source: National Assessment Synthesis Team Foundation Technical Review Document, "Chapter 5: Great Plains." | |

### *h. West – Model Contradictions*
**(California, Utah, Nevada, Arizona)**

<table>
<tr><th>Canadian Model</th><th>Hadley Model</th></tr>
<tr><td colspan="2">Climate Change</td></tr>
<tr><td>↑ Winter temperature warms by 12.8 °F and summer temperature by 7.7 °F by 2090</td><td>↑ Winter temperature warms by 8.8 °F and summer temperature by 8.3 °F by 2090.</td></tr>
<tr><td>↑ Increase in precipitation over southern California, but potential for decreased precipitation in some parts of the Rocky Mts.</td><td>↓ New version of Hadley model shows decrease in precipitation over California, most of Nevada and Arizona, and southwestern Utah. (Old model showed increase in precipitation over southern California)</td></tr>
<tr><td>↑ No change in summer precipitation</td><td>↓ Summer rain decreases.</td></tr>
<tr><td>↑ Risk of fire frequency and intensity goes up</td><td>↑ Risk of fire frequency and intensity goes up</td></tr>
<tr><td colspan="2">Agriculture</td></tr>
<tr><td colspan="2">↓ Agriculture could be at particular risk from hotter and drier conditions. The amount of water available for irrigation may be reduced substantially.<br>↑ The model results show increases in yields for many crops and small changes in demand for irrigation water for major western states and in a few cases, significant decreases in demand.</td></tr>
<tr><td colspan="2">Water</td></tr>
<tr><td colspan="2">↓ ↑ For the 2030s models disagree on whether the rest of the region will see reduced or increased runoff<br>↑ ↓ Both models show increased soil moisture. However, since precipitation is reported to decline in the new version of the Hadley model, presumably soil moisture would also decrease.</td></tr>
<tr><td>↑ Earlier spring runoff can increase risk of spring flooding.</td><td>↓ If reduced or even small increases in precipitation, runoff could be reduced. Drier conditions could result in a decrease in flood potential and mudslides.</td></tr>
<tr><td>↑ Higher runoff could ease water supply stresses and reduce the demand for surface water and groundwater for such purposes as irrigation and watering lawns.</td><td>↓ Both groundwater recharge and reservoir supplies could be reduced as higher temperatures increase evaporation.</td></tr>
</table>

## *WEST - Continued*

### *Forests*

| ↑ (increase) | ↓ (decrease) |
|---|---|
| ↑ Across the West, a wetter climate would increase forest productivity.<br>↑ There would be a substantial expansion of conifer forests and a substantial reduction of arid lands, particularly in southern California, southern Nevada, and western Arizona.<br>↑ An increase in precipitation would increase biomass and water supplies, and enhance grazing land for ranching. | ↓ If conditions become drier rather than wetter, productivity of vegetation could decrease.<br>↓ There could be a shift from forests, woodlands and shrublands to grasslands and deserts.<br>↓<br>↓ A decline in precipitation would make the region more arid, reduce vegetation productivity and water supplies, and foreclose much of ranching. |

Source: National Assessment Synthesis Team Foundation Technical Review Document, "Chapter 6: West."

### *i. Pacific Northwest – Model Contradictions*
**(Washington, Oregon, and Idaho)**

<table>
<tr><th>Canadian Model</th><th>Hadley Model</th></tr>
<tr><td colspan="2">

Climate Change

"The coarse spatial resolution of General Circulation Models (GCMs) is particularly troublesome for replicating the spatial character of climate in the Northwest, which is strongly shaped by the region's abrupt topography. The GCMs simulate a climate for the region that is too "maritime"—wetter than the true regional climate, and milder in both winter and summer. The biases are more acute for precipitation than for temperature. Therefore, in order to project future climate, each model's bias relative to the present climate is removed." (Source: National Assessment Synthesis Team Foundation Technical Review Document, "Chapter 7: Pacific Northwest.")

! In other words, even though the GCMs can't replicate the current climate, they are used to forecast the future climate

↑ Models show regional warming continuing at an increased rate in the next century, in both summer and winter. Average warming over the region reaches about $3^{o}$ F by the 2020s, about 5 $^{o}$ F by the 2050s.<br>
↓ ↑ Annual precipitation changes through 2050 over the region range from a small decrease (-7% or 2") to a slightly larger increase (+14% or 4")<br>
↑ Precipitation increases are concentrated in winter, with little change or a decrease in summer. Because of this seasonal pattern, even the projections that show annual precipitation increasing show water availability decreasing.<br>
↑ Beyond 2050 the projected trend to a warmer, wetter regional climate continues in both the Hadley and Canadian models, with winter warming substantially more than summer in both models.
</td></tr>
<tr><td>↑ By 2090s, average summer temperatures have risen by $7^{o}$ F and winter temperatures have risen by $9^{o}$ F.<br>↑ Precipitation increases over the region range from 20% to 50%.</td><td>↑ By 2090s, average summer temperatures have risen by $6^{o}$ F and winter temperatures have risen by $11^{o}$ F.<br>↑ Precipitation increases over the region range from 3% to 20%.</td></tr>
<tr><td colspan="2">

Agriculture

↑ Under all scenarios, dryland yields for most crops are projected to increase through the next century.<br>
↓ The exception was potatoes, whose dryland yields by 2090 declined by as much as 30-35%, with the largest declines in Idaho.
</td></tr>
</table>

## PACIFIC NORTHWEST - Continued

| |
|---|
| ***Water*** |
| ↑ ↓All of the models studied differ in the relative size of winter and summer changes, and consequently, on whether total annual flow increases or decreases. Projections for annual flow in the 2020s in four models range from a 22% increase to a 6% decrease; for the 2050s, projected changes range from a 10% increase to a 19% decrease. |
| ***Forests*** |
| ↓ An early study using observed correlations between forest communities and climate predicted forest dieback and sagebrush steppe expansion, but the analysis assumed no change in water use efficiency or tree productivity from $CO_2$ enrichment.<br>↑ A more recent study projects expansion of forests in the Northwest, assuming that elevated $CO_2$ increases forests' water-use efficiency. |
| ***Salmon*** |
| **?** Climate models presently lack the detail to project changes in many specific environmental factors that are most important for salmon, such as the timing of seasonal coastal upwelling, variations in coastal current and vertical stability of the water column. But increased winter flooding, reduced summer and fall flows, and warmer stream and estuary temperatures are all harmful for salmon. |
| ***Coastal*** |
| ↑ Models predict climate warming will raise mean sea level 10 to 35 inches by 2100, as opposed to the 4 to 10 inch rise of the $20^{th}$ century.<br>↓ Extensive development on coastal bluffs and near beaches has placed considerable valuable property at risk from erosion and landslides.<br>↑ Could assign more of the risk of living in a coast zone to property-owners, through incorporating geological assessment into property-insurance.<br>**?** Little long-term data is available on coastal effects of climate variability. |
| Source: National Assessment Synthesis Team Foundation Technical Review Document, "Chapter 7: Pacific Northwest." |

## 3. The U.S. National Assessment Climate Scenarios Are Not Valid

Since it is not possible to predict future climate, the approach used in the U.S. National Assessment (USNA), and most other studies of this type, is to develop climate scenarios. The Intergovernmental Panel on Climate Change (IPCC) describes scenarios as follows:

> Scenarios are images of the future, or alternative futures. They are neither predictions nor forecasts. Rather, each scenario is one alternative image of how the future might unfold … As such they enhance our understanding of how systems behave, evolve and interact. They are useful tools for scientific assessments, learning about complex system behavior and for policymaking and assist in climate change analysis, including climate modeling and the assessment of impacts, adaptation and mitigation." [4]

Based on a single set of assumptions, the USNA relied on two climate scenarios, one from the Canadian Climate Centre General Circulation Model, and the other from the second generation Hadley Centre (U.K.) General Circulation Model. General Circulation Models (GCMs) are three-dimensional computer models that use our current understanding and knowledge base of physical and chemical phenomena occurring in the atmosphere and oceans to project the changes in temperature and precipitation that would occur if the factors affecting climate (greenhouse gas emissions, solar radiation, etc.) change.

For these scenarios to be useful images of the future, they must have been generated with a technique that used:

(1) plausible inputs,
(2) in models which accurately represent current regional climate and climate variability -- if they can't match current conditions, there is no reason to assume that they will make accurate projections of future conditions-- and
(3) the best available modeling techniques to generate scenario details.

The USNA fails on all three counts.

### *a. The National Assessment Models Did Not Use Plausible Inputs*

To make accurate projections, GCMs have to use correct inputs. The inputs the USNA used are seriously flawed.

[4] Nackicenovic, N., *et al*. (2000): Special Report on Emission Scenarios: A Special Report of Working Group III of the Intergovernmental Panel on Climate Change, Cambridge University Press, Pg. 23.

For both model simulations, the USNA assumed that the atmospheric concentration of greenhouse gases would increase by 1% per year and that the concentration of sulfate aerosols would double by 2100. This is a convention that has been adopted by climate modelers to allow them to compare their models.

While this is a useful exercise for comparing climate models, it is a poor choice as a basis for climate scenarios. Currently, the atmospheric concentration of the greenhouse gases (as measured by equivalent $CO_2$) that would be subject to control under the Kyoto Protocol is increasing by about 0.5% per year. In the near-term future, to 2030, we might see a somewhat higher rate of increase.

It is critical to note that the single USNA 1% per year growth emissions scenario projects global $CO_2$ emissions to nearly <u>triple</u> by 2100. This is in startling contrast to the best current source for emissions scenarios in the recently issued Intergovernmental Panel on Climate Change (IPCC) Special Report on Emissions Scenarios which recommends using a minimum set of six emissions scenarios covering a wide range of potential $CO_2$ emissions levels by 2100. Two of the six scenarios project $CO_2$ emissions levels in 2100 to be *lower* than current levels, two scenarios project higher $CO_2$ emissions than current levels but a *one-third lower* than the single scenario used by the USNA, and only the final two IPCC scenarios project $CO_2$ emissions higher than those used in the USNA. [5]

The USNA justified its choice of 1% per year increase in atmospheric concentrations of greenhouse gases by saying that this rate approximates the IPCC "business-as-usual scenario." The IPCC "business-as-usual" scenario, officially designated IS92a, is one of six scenarios developed by the IPCC in 1992. In 1994, well before the start of the USNA process, the IPCC reviewed the use of its 1992 scenarios, and concluded that dependence on IS92a was a poor strategy. In its recent Special Report on Emissions Scenarios, IPCC said:

> "Another important recommendation of the 1994 IPCC review was that, given the uncertainty about future climate change, analysts should use the full range of IS92 emissions as input to climate models rather than a single scenario. This is in stark contrast to the actual use of one particular scenario in the set, the IS92a scenario, as the reference case in numerous studies. In fact, the IS92a scenario is often referred to in climate change modeling and impact studies as the "business-as-usual" scenario and used as the only reference emissions trajectory. The review concluded that the mere fact of the IS92a being an intermediate, or central, $CO_2$ emissions scenario at the global level does not equate to it being the most likely scenario. Indeed, the conclusion was that there was no objective basis on which to assign likelihood to any of the scenarios. Furthermore, the IS92a scenario was shown to be "central" for only a few of its salient characteristics such as global population growth, global economic development and global $CO_2$ emissions. In other ways, IS92a was found not to be

[5] Nackicenovic, N., *et al*. (2000): Special Report on Emission Scenarios: A Special Report of Working Group III of the Intergovernmental Panel on Climate Change, Cambridge University Press. Table 3a.

central with the published literature, particularly in some of its regional input assumptions." [6]

The 1994 IPCC review identified a number of other shortcomings of the IS92 scenarios, and in 1996, IPCC approved development of a new set of scenarios. In its Terms of Reference for this new effort, IPCC said:

> "Much has changed in the period following the creation of the IS92 scenarios. Sulfur emissions have been recognized as a more important radiative forcing factor than other non-$CO_2$ greenhouse-related gases, and some regional control policies have been adopted. Restructuring in the states of Eastern Europe and the Former Soviet Unions has had far more powerful effects on economic activity and emissions than were foreseen in the IS92 scenarios. For some regions these scenarios are not representative of those found in the literature, The advent of integrated assessment models has made it possible to construct self-consistent emissions scenarios that jointly consider the interactions between energy, economy and land-use changes." [7]

Despite the shortcomings of dependence on IS92a as a sole emissions scenario, which were well-recognized before the start of the USNA process, the USNA chose a 1% per year increase in atmospheric concentrations of greenhouse gases as its only emissions scenario and justified that choice based on its similarity to the IS92a scenario. A far more realistic approach would have been to choose a range of emissions scenarios.

### *b. USNA Models Do Not Match Current Climate Over the U.S.*

A critical test for any climate model is how well it simulates current climate. Both of the models used in the National Assessment have been found to have significant shortcomings in this area.

Doherty and Mearns (1999) carried out detailed comparisons of the simulation of current climate from both the Canadian Climate Centre (GCGMI) and Hadley Centre (HADCM2) models with actual observations over the 1921 - 1980 period. They found that there were significant discrepancies between simulated and actual climate for both models, with the Canadian Climate Center model showing larger deviations from actual climate than the Hadley Centre model. Their study covered a large part of the Western Hemisphere, but only results directly relevant to the U.S. are presented here. On temperature, Doherty and Mearns concluded:

> "Another major area of disagreement over the US occurs over the central plains and the Midwest reaching up to the Canadian prairies in the summer, where both AOGCMs (atmosphere-ocean coupled general circulation models) estimate temperatures of 1 - 3 $^{o}$C (reaching a maximum difference of 6 $^{o}$C ) higher than

[6] Nackicenovic, N., *et al*. (2000), Pg. 65-66.
[7] Nackicenovic, N., *et al*. (2000), Pg. 324.

> observations. The CGCMI simulates this region of higher temperature to extend eastward over the Northeast US in summer but the warm bias is much smaller in autumn. The HADCM2 simulation exhibits a similar region of warmer temperatures in autumn between 1 - 3 $^{o}$C.” [8]

On precipitation, the authors conclude:

> “The major fractional differences in precipitation that occur over the Rockies extending from Canada to the Northwest and Basin and Range represent a fractional overestimation in precipitation of 100% to 500%, predominantly in the CGCMI simulation. The relative errors are more intense and extensive in the CGCMI simulations than in that of the HADCM2. In the case of the latter, overestimations in precipitation above 200% are mainly confined to Alaska in spring. The drier areas of the Southeastern US and lower Mississippi Basin represent an underestimation in precipitation of around 20% to 50% in both models with a small confined area which reaches 100% in winter in CGCMI simulations.” [9]

### *c. USNA Models Do Not Match Current Climate Variability*

Many of the impacts evaluated in the USNA are the result of climate extremes, not average climate. Therefore it is important to know how well the models do in estimating climate extremes. One measure of the ability of models to predict climate extremes is their ability to reproduce current climate variability.

The performance of the Hadley Centre model in matching current climate variability has been studied by a number of researchers, including its developers. All researchers agree that the Hadley Centre model does poorly in simulating the observed variability of climate. In the interest of space, the results of one of these studies will be reported in detail, and the others only briefly summarized.

In the abstract of their paper reporting on an evaluation of the HADCM2 model in simulating regional climate, Giorgi and Francisco (2000) conclude that the model does not reproduce well observed interannual variability.[10] The body of the paper provides the following detail for temperature:

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[8] Doherty, R. and L.O. Mearns, (1999): A Comparison of Simulations of Current Climate from Two Coupled Atmosphere-Ocean Global Climate Models Against Observations and Evaluation of Their Future Climate, Report to the National Institute for Global Environmental Change (NIGEC), Pg. 5.

[9] Doherty, R. and L.O. Mearns, (1999): Pg. 6.

[10] Giorgi, F. and R. Francisco (2000): "Uncertainties in regional climate change prediction: a regional analysis of ensemble simulations with the HADCM2 coupled AOGCM," *Climate Dynamics*, **16**: 169-182, Pg. 169.

> "Compared with observations, the model overestimate interannual standard deviation of temperature (and thus the temperature interannual variability) during JJA (June, July and August) over all regions and by up to a factor exceeding 2. During DJF (December, January and February) the model underestimates temperature variability over the North American, northern Europe and Asian Regions, while it overestimates it over other regions." [11]

and for precipitation:

> "The model performance in simulating interannual variability of seasonal precipitation is poor. Figure 5 shows that the model tends to overestimate the interannual standard deviations (and thus interannual variability) of precipitation for both DJF and JJA …" [12]

Similar results were reported by Tett, *et al.* (1997)[13] of the Hadley Centre, who found that the model overestimated temperature variability over land; and by Wilby and Wigley (1999)[14], who found that the Hadley Centre model did not reproduce the observed correlations between daily precipitation and a number of atmospheric variables in six regions across the U.S.

The only similar study on the Canadian Climate Centre model was published by its developers, who claim that on a global basis it reproduces climate variability well.[15]

### *d. Even Though Inadequate, The Best Available Modeling Tools Were Not Used to Generate Scenario Details*

The IPCC concluded the following about the use of atmosphere-ocean coupled general circulation models (AOGCMs) for projecting climate at the regional level:

> "The global climate models used for future projections are run at fairly coarse resolution and do not adequately depict many geographic features (such as coastlines, lakes and mountains), surface vegetation, and interactions between the atmosphere with the surface (sic) which become more important on regional scales. Considerable spread exists among model projections on the regional scale even when climate model experiments are driven by the same future radiative forcing scenario. …

[11] Giorgi, F. and R. Francisco (2000), Pg. 174.
[12] Giorgi, F. and R. Francisco (2000), Pg. 175.
[13] Tett, S.F.B., T.C. Johns and J.F.B. Mitchell, 1997: "Global and regional variability in a coupled AOGCM," *Climate Dynamics*, **13**: 303-323.
[14] Wilby, R. L. and T.M.L. Wigley, 1999: "Precipitation predictors for downscaling: observed and general circulation model relationships," International Journal of Climatology (in press).
[15] Flato, G. M., *et al.*, 2000: "The Canadian Centre for Climate Modelling and Analysis global coupled model and its climate," *Climate Dynamics* (in press)

> Because of these problems, no information on future regional climate change is presented here." [16]

The "coarse resolution" problem is created by limitations in computing capability. GCMs divide the atmosphere and oceans into a three dimensional grid. The grid boxes are typically 300 km on a side and vary in height. A GCM can have more than 150,000 of these grid boxes. To model climate, a set of complex mathematical equations must be solved for each of these grid boxes. This requires enormous amounts of computer time, weeks to months on the fastest super-computers, for a full projection over a 100-year timeframe. While it would be desirable to use smaller grid boxes, halving the horizontal dimensions of the grid boxes, making them 150 km on a side rather than 300 km, increases the computing requirement by a factor of four. To keep computer requirements within bounds, large grid boxes must be used.

Several techniques have been developed to address the coarse resolution problem. The most successful of these is regional climate modeling, which takes the output from a GCM and uses it as input for a model with much smaller grid squares that covers a limited area rather than the whole Earth. The Hadley Centre has done this and describes the process as follows:

> "A regional climate model describes mathematically the behavior of the atmosphere, in the same way as a global model. But it does this with much higher resolution, typically 50 km, and over a smaller area (domain), typically a 5000 km square. It is driven at the boundaries by simulations or predictions of large scale climate from a global model." [17]

The Hadley Centre used this approach to simulate winter rainfall over the UK, using its standard model with 300 km resolution, and two regional approaches, 50 km resolution and 25 km resolution. The standard model simulation bears no relationship to the actual rainfall pattern; 50 km resolution begins to show the detail in the actual pattern and 25 km resolution provides good agreement.[18]

The USNA used regional climate modeling, but only for a very limited part of the country, "e.g., the West Coast with its Sierra Nevada and Cascade Mountains." For the remainder of the country, the USNA used a linear approximation technique, called VEMAP, which is described in the draft USNA report as follows:

> "… what is done is to make the assumption that the differences between the models and observations for the 20th century are systematic -- that is, that the differences

[16] Houghton, J. T., *et al.* , 1996: Climate Change, 1995: The Science of Climate Change, Cambridge University Press, Pg. 31.
[17] Jenkins, G. *et al.* (2000): "Regional Climate Predictions for National Vulnerability Assessments: Capacity Building in Developing Countries," The Met Office, Bracknell, UK
[18] Jenkins, G. *et al.* (2000):

> between models and observations are a result of limitations in the model formulations and will be present in simulations for both the 20th and 21st centuries." [19]

To implement this procedure, the USNA determined the monthly average temperature, as well as monthly maximum and minimum temperatures, for the 1961 - 1990 baseline period at a large number of points across the U.S. It then used the two models to calculate differences between the baseline period and a range of dates in the 21st century for monthly average, maximum and minimum temperatures for each grid square. To create its two climate scenarios, the USNA added these differences to the actual baselines. Thus, if the Hadley Centre model projected that average temperature would rise 5$^{o}$ F between the baseline period and 2100 for a given grid square, the Hadley Centre climate scenario for 2100 was created by adding 5$^{o}$ F to the actual average baseline period temperature for each point in that grid square. If the Canadian Climate Centre model projected 7$^{o}$ F, the Canadian Climate Centre model scenario for 2100 was created by adding 7$^{o}$ F to actual baseline temperatures.

For precipitation a slightly different approach was used. Instead of differences between precipitation in the baseline period and a range of dates in the 21st century, ratios were used. Thus, if the Hadley Centre model predicted 40% more precipitation in the 2080s in a particular grid square,  the Hadley Center scenario for 2100 would show a 40% increase over actual baseline monthly average precipitation for each point in that grid square.

After describing this approach, the USNA draft discusses its limitations, and concludes:

> "What is most clear is that, for future assessments meso-scale models need to be used more rigorously and accurately simulate region patterns of change in precipitation." [20]

The meso-scale models referred to in this quote are the regional climate models that were described earlier. It is not clear why the concern is limited to precipitation. Many of the problems discussed would also affect temperature estimates.

The USNA does not provide any evaluation to justify the VEMAP approach, and there are good reasons for questioning its validity. The difference between model simulations and actual climate during the baseline period can be considered a measure of the net effect of all that we do not understand about modeling climate. Assuming that the difference between model projections of the climate in 2100 and actual climate in 2100 will be the same as the difference between model simulations of current climate and actual climate, is equivalent to saying that we know as much about the climate in 2100 as we know about current climate. This is clearly not the case.

While the physical and chemical processes that affect climate are reasonably well known in a qualitative sense, our ability to model them quantitatively is poor. This is why while both the Hadley Centre and Canadian Climate Centre models incorporate essentially the same set of physical processes, they arrive at very different projections for future climate.

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[19] USNA Draft, Chapter 1, Pg. 58.
[20] USNA Draft, Chapter 1, Pg. 59.

From the IPCC evaluation, the Hadley Centre study, and USNA's own conclusion, it is clear that the modeling techniques that the USNA used are incapable of presenting realistic projections of future climate at the regional scale the assessment required. A better tool, i.e., regional modeling, was available, but was not used.

Even within the National Assessment effort, the widely recognized weaknesses of regional modeling were acknowledged. As noted in a report by the Health Section of the U.S. National Assessment:

> "[M]ethods to project changes in climate over time continue to improve, **but climate models are unable to accurately project regional-scale impacts.**" [21]

Indeed, even the authors of the Hadley Centre model, one of the two models used in the National Assessment, issued an explicit caution against the use of global climate models in generating regional impact assessments. According to the Hadley Centre:

> "Global climate models (GCM) can provide scenarios of changes in climate down to scales of 1000km or so at best. Where the terrain is reasonably flat and uniform, and away from coasts, these scenarios may be adequate, given the inherent uncertainties in all model predictions. But in areas where coasts and mountains have a significant effect on weather (and this will be true for most parts of the world), scenarios based on global models will fail to capture the regional detail needed for vulnerability assessments at a national level.
>
> "RCMs [Regional Climate Models] do not replace or supercede GCMs; indeed they give added impetus to the development of GCMs. The agreement between regional predictions from global models is poor; hence improved regional prediction will only be achieved if global model performance is improved in parallel." [22]

### *e. Conclusions*

The USNA used a single, non-representative emissions scenario to drive two climate models which do a poor job of representing current climate and climate variability in the U.S. The USNA then uses the output of these models to create scenarios using a

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[21] Report of the Health Section of the U.S. National Assessment, "The Potential Health Impacts of Climate Variability and Change for the United States: Executive Summary of the Report of the Health Sector of the U.S. National Assessment," published in *Environmental Health Perspectives*, Volume 108, Number 4, April 2000

[22] Haley Centre for Climate Prediction and Research, "Regional Climate Predictions for National Vulnerability Assessments", presented at the UN Framework Convention on Climate Change, 12th meeting of the Subsidiary Bodies, June 2000.

statistical technique which is based on a questionable assumption, that we know as much about future climate as we know about current climate. The result is two climate scenarios in which little confidence can be placed.

The USNA could have done better. The problems with the emissions scenario USNA chose were well documented before the start of the program. Better modeling techniques were also available, and, in fact, used to only a limited extent in the USNA. But a core problem with the U.S. National Assessment effort is simply that reliable regional modeling of climate change impacts is not currently possible, and that was known when the National Assessment process was initiated.

# 4. Vulnerability to Climate Change Is Overstated

## *a. Overview*

The US National Assessment's treatment of vulnerability to climate change, while voluminous, is misleading for two key reasons:

- The Assessment is based on climate scenarios that overstate the potential change in climate to 2100. Had the Assessment used the best techniques for evaluating future climate -- a balanced set of models and a reasonable range of emissions scenarios -- most of the potential impacts it considered for 2100 would have been milder than the ones actually considered.

- The Assessment is based on completely inadequate socioeconomic information. While acknowledging that climate conditions and societal conditions both affect climate impacts, the Assessment provides no information on the effects of socioeconomic variables on the degree of impact in 2100.

In addition, the Assessment misrepresents factors that can affect the degree of impacts.

- The potential negative impacts of climate change on public health are overstated.

  – The potential for increased heat-related deaths is highlighted, but there is no indication of the fact that these deaths can be eliminated with proper adaptation measures. Reductions in cold-weather deaths are downplayed, even though studies in Australia and the UK indicate that they can be substantial.

  – Much is made of the potential health effects of extreme weather events without pointing out that there is no evidence that the frequency or intensity of most of these events would increase in a warmer world.

  – The effect of temperature on the severity of air pollution is highlighted without discussing the countervailing impact of lower emissions as the result of laws and regulations that have already been enacted.

  – A claim is made that water- and food-borne diseases would increase without pointing out that well-known control steps can control most, if not all, of these diseases.

  – Concern is raised about vector-borne diseases in the Overview document which is not supported by the balanced discussion in Chapter 15.

- The impact of climate change on El Nino and hurricanes is overstated.

- Model projections of increased El Nino-like conditions are used to justify concerns about negative impacts on agriculture without taking into account the high level of uncertainty and scientific debate as to whether El Nino is likely to intensify in the future.

- Chapter 4 (Northeast) raises concern about increased hurricane intensity and the Overview document states that hurricane intensity could increase 5 - 10%, despite the fact that such increases are highly uncertain, as pointed out in Chapters 5 and 11.

- The Assessment places undue emphasis on impacts that are part of on-going trends.

  - The Overview implies that climate change will cause falling agricultural commodity prices and stress farmers, even though these prices have been falling for decades. In addition, these conclusions do not reflect results reported by Mendelsohn and Neumann, who found that the agricultural sector would benefit through 2060 under a wide range of climate change conditions.[23]

  - Climate change is also projected to cause the migration of the maple sugar industry from New England to Canada, even though the industry has been moving northward for more than 70 years, through periods of both rising and falling temperature.

Finally, even though the Assessment purports to be about both vulnerability and adaptation, the treatment of adaptation is cursory and inadequate. As admitted in Chapter 3:

> "In this first Assessment, potential climate adaptation options were identified, but their feasibility, costs, effectiveness, or the likely of their actual implementation were not assessed. Careful assessment of these will be needed." [24]

It is well recognized that adaptation measures can greatly reduce the impacts and cost of climate change. Presenting a detailed assessment of U.S. vulnerabilities to climate change, without an equally detailed assessment of what the U. S. can do to adapt to climate change, is a scare tactic that is both misleading and irresponsible.

### *b. Overstatement of Potential Climate Change to 2100*

As was documented in the section on models, a single emissions scenario was used to generate both climate scenarios used by the USNA. This emissions scenario projects global $CO_2$ emissions to nearly triple by 2100. The best current source for emissions

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[23] Mendelsohn, R. and J. E. Neumann, 1999. *The Impact of Climate Change on the United States Economy.* Cambridge University Press, Pg. 316.
[24] USNA Draft, Chapter 3. Pg. 8.

scenarios is the recently issued Intergovernmental Panel on Climate Change (IPCC) Special Report on Emissions Scenarios which recommends using a minimum set of six emissions scenarios covering a wide range of potential $CO_2$ emissions levels by 2100. Two of the six scenarios project $CO_2$ emissions levels in 2100 to be *lower* than current levels, two scenarios project higher $CO_2$ emissions than current levels but one-third lower than the single scenario used by the USNA, and the final two project $CO_2$ emissions higher than those used in the USNA. [25]

In addition, the two models used in USNA are not a reasonable representation of the range of available models. The USNA states:

> "Compared to the range (of global average temperature increase) suggested for the year 2100 by IPCC results, the Hadley Model scenario projects warming that is slightly above the central IPCC estimate of about 4$^{o}$ F (2.4$^{o}$ C) after adjusting for the change in baseline years. The Canadian Model scenario projects warming that is slightly above the high-end of the IPCC suggested range of about 6.75$^{o}$ F (3.75$^{o}$ C) …" [26]

If the Canadian Centre model is used, it should be balanced with a model that is at the low end of the range of temperature projections.

Had the USNA used the best techniques for evaluating future climate -- a balanced set of models and a reasonable range of emissions scenarios -- most of the potential impacts it considered for 2100 would have been milder than the ones it actually considered.

### *c. Inadequate Socioeconomic Input to the Assessment of Impacts*

Chapter 3, Socioeconomic Context for Climate Impact Assessment, correctly states:

> "Climate conditions and societal conditions jointly cause climate impacts. Because of this joint causation, making a coherent assessment of climate impacts requires careful, systematic assumptions about future socioeconomic conditions as well as future climatic conditions. However challenging it is to model and project future climate, projecting future socioeconomic conditions is more so." [27]

The USNA failed to even try to meet this challenge. The Overview document dismisses the possibility of providing such information:

> "A host of other factors are also likely to affect the ease with which society can adapt to, or take advantage of, climate variability and change. For particular regions or

[25] Nackicenovic, N., *et al*. (2000): Special Report on Emission Scenarios: A Special Report of Working Group III of the Intergovernmental Panel on Climate Change, Cambridge University Press. Table 3a.
[26] USNA Draft, Chapter 1, Pg. 32.
[27] *Ibid.*, Chapter 3, Pg. 3 - 4.

> sectors, factors likely to shape climate vulnerability include local zoning ordinances, housing styles, building codes, popular forms of recreation, the age and specialization of capital in particular industries, world market conditions, and distribution of income. To further complicate matters, many of these factors are likely to be influenced by climate variability and change, and to influence each other. Trying to project all such relevant factors, or to model their interactions, would be impossible."[28]

Instead, the USNA used the following approach to provide a very limited amount of socioeconomic input:

> "A working group of the NAST (National Assessment Study Team) was charged with developing scenarios for the socioeconomic assumptions necessary for the assessment. Because of the complexity and diversity of the socioeconomic characteristics that might be important contributors to impacts and vulnerability, and because of the highly decentralized nature of the National Assessment process, this working group judged it infeasible to attempt to develop fully detailed socioeconomic scenarios centrally. … Rather the working group attempted to balance the assessment's competing needs for reflecting regional concerns and expertise, while maintaining enough consistency to allow national-level synthesis, by recommending a two-track approach to scenario development, partly centralized and partly decentralized.
>
> "The centralized track comprised a few key socioeconomic variables likely to influence many domains of impact, such as population, economic output, and employment. For these, where nationwide consistency was most important, the working group developed three internally consistent socioeconomic scenarios, which were used in all region and sector studies….
>
> "The decentralized track was to be used when a particular analysis required future values of more specific or local socioeconomic characteristics to be defined. In this case, the relevant assessment team was asked to develop and document the required assumptions themselves." [29]

While this process sounds logical and impressive, it does not appear to have had any impact on the result of the assessment. None of the key findings reported in the Overview discuss different levels of impacts or concerns based on differences in socioeconomic assumptions. The discussion of the effect of socioeconomic variables is limited to the following general statement:

> "If economic growth is higher, society is likely to be more able to take advantage of the opportunities a changing climate presents and more able to cope with its negative impacts. Wealthier, industrialized societies derive less of their incomes from strongly-climate related activities than more traditional societies. With more technology and

[28] *Ibid.*, Overview, Pg. 31.
[29] *Ibid.*, Pg. 9 - 10.

> infrastructure, wealthy societies also have more resources to support adaptation, and can more easily endure climate-related losses. Within societies, some will likely face greater burdens or greater opportunities than others. It is also possible that rapid economic growth can increase vulnerability, by increasing pollution (including greenhouse gas emissions), congestion, demand for land and resources, and stresses on natural ecosystems, and possibly their vulnerability to climate change." [30]

While this statement is undoubtedly true, it stands in vivid contrast to the specific detail offered on projections of climate change, with estimates of temperature rise, sea level rise, increased heat index, decreased soil moisture, and many other aspects. If vulnerability is a function of both changes in climate conditions and changes in societal conditions, doesn't the USNA have an obligation to provide equal detail on both?

### *d. Potential Negative Health Effects of Climate Change are Overstated*

Chapter 15 of the USNA lists five potential effects of climate change on health:

1. temperature-related morbidity and mortality,
2. health effects of extreme weather events,
3. air pollution-related health effects,
4. water- and food-borne disease, and
5. insect-, tick-, and rodent-borne diseases.

All of these health threats are potential problems today. The U.S. health system deals with them routinely and successfully. Climate change could affect the magnitude or priority of some health threats, but it will not introduce any new ones. The authors of the chapter make no quantitative statements about risk, excusing themselves with the following:

> "Projections of the extent and direction of some potential health impacts of climate variability and change can be made, but there are many layers of uncertainty. First, methods to project changes in climate over time continue to improve, but climate models are unable to accurately project regional-scale impacts. Second, basic scientific information on the sensitivity of human health to aspects of weather and climate is limited. …
>
> "It is also difficult to anticipate what adaptive measures might be taken in the future to mitigate risks of adverse health outcomes, such as vaccines, disease surveillance, protective technologies (e.g., air conditioning or water filtration/treatment), use of weather forecasting and warning systems, emergency management and disaster preparedness programs, and public education." [31]

Chapter 15 overstates the potential threat of climate change to public health by:

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[30] *Ibid.*, Overview, Pg. 29.
[31] *Ibid.*, Chapter 15, Pg. 8.

- exaggerating the likelihood of climate and weather changes that would create health threats, and
- not discussing some of the well-known adaptation measures that could be used to counter whatever threat arises.

In addition, the threat to public health is further exaggerated in the Overview, which misstates the results of Chapter 15. A more detailed analysis of each of the five areas covered in the chapter is presented below.

### (i) Temperature-related Morbidity and Mortality

The USNA overstates the risk of increased hot weather deaths, while ignoring evidence that there may be large decreases in cold-weather deaths.

In stressing the potential increase in deaths due to heat waves, the USNA cites the 1995 Chicago heat wave that is claimed to have resulted in 700 excess deaths.[32] Some researchers have challenged this number, citing, among other things, a change in definition of cause of death. The Chapter continues with the following observation:

> "There is evidence that heat-related illnesses and deaths are largely preventable through behavioral adaptations, including the use of air-conditioning and increased fluid intake, although the magnitude of mortality reduction cannot be predicted." [33]

As has often been pointed out, U.S. cities of the desert Southwest, which have their share of poor, old and vulnerable people, routinely experience temperatures higher than those claimed to have killed hundred of people in Chicago without an increase in mortality. As the USNA itself points out:

> "Human societies and economies have demonstrated great adaptability to wide-ranging environmental and climatic conditions found throughout the world, and to historical variability. Wealthy industrial societies like the U.S. function quite similarly in such divergent climates as those of Fairbanks, Alaska and Orlando, Florida."[34]

The correct assessment of the risk of increased heat mortality is that it can be eliminated with appropriate adaptation measures.

Chapter 15 acknowledges that death rates are higher in the winter than in the summer and that it is possible that milder winters could reduce deaths in winter months, but then concludes:

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[32] *Ibid.*, Pg. 11.
[33] *Ibid.*, Pg. 12.
[34] *Ibid.*, Overview, Pg. 32.

> "The net effect on winter mortality from climate change is therefore extremely uncertain, and the overall balance between changes in summer and winter-related deaths is unknown." [35]

However, this uncertainty does not stop the Overview document from making a stronger statement:

> "There is also some chance that warming will reduce cold-related mortality, a trend that will also interact with the aging of the populations, although data suggest a weaker effect than for heat." [36]

If such data exist, they should be discussed in the Foundation document on Health, particularly since they contradict studies published for other countries. Studies in both Australia[37] and the UK[38] indicate that the decrease in winter mortality will be greater than the increase in summer mortality. A follow-up study for the UK estimated a decrease in annual cold-related deaths of 20,000 by the 2050s, a decrease of 25%.[39] Why would there not be a similar trend in the U.S.?

### (ii.) Health Effects of Extreme Weather Events

The discussion of this topic starts from the premise that climate change may alter the frequency, timing, intensity, and duration of extreme weather events, and that such events kill people. There is no question that extreme weather can be deadly; the question is whether climate change, even to the extreme projected in the USNA, is likely to result in changes in extreme weather events? For most extreme weather events, the answer is that there is no evidence.

The types of extreme weather that are of concern, and information available on their trends under climate change include:

| | |
|---|---|
| Blizzards and snowstorms | Likely to decrease if weather is warmer |
| Hurricanes | Discussed in detail below - no evidence of increase if weather is warmer |

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[35] *Ibid.*, Chapter 15, Pg. 12.
[36] *Ibid.*, Overview, Pg. 30.
[37] Guest, C. S., *et al.* 1999: Climate and mortality in Australia: retrospective study, 1979-1990 and predicted impacts in five major cities in 2030, *Climate Research*, **13**, 1 - 15.
[38] Langford I. H. and G. Bentham, 1995: The potential effects of climate change on winter mortality in England and Wales, *International Journal of Biometeorology,* **38**, 141-147.
[39] Donaldson, G. C., e*t al.*, 2000: The potential impact of climate change on heat- and cold-related mortality and morbidity. In: *Health Effects of Climate Change in the U.K.* (forthcoming).

| | |
|---|---|
| Tornadoes | No evidence of increase if weather is warmer - the number of days with significant tornadoes in the U.S. decreased in the 1970s and 1980s even though average temperature rose.[40] |
| Floods | Projected to increase if precipitation increases |

The USNA's concerns about increased health impacts due to increased extreme weather is overstated.

### (iii.) Air Pollution Related Health Effects

The concern raised in this section is that increased temperature will increase both the formation of ground-level ozone and its negative health effects. The improvements in air quality achieved since 1970 are acknowledged, but there are no projections of the further improvements that will be achieved under the environmental laws and regulations already on the books. The Assessment makes no attempt to project future air quality, merely states that some of the factors that affect air quality will change in the future.

Again, the potential health impacts of climate change have been overstated. The relationship between temperature and ozone formation is well known, and air quality models that would allow projection of the combined effect of further reductions in emissions and potential increases in temperature exist. There is no indication that the USNA considered use of these models or any other tool for projecting future air quality. Instead it looked only at the potential negative impacts of future trends on air quality and concluded that there would be health problems as a result.

### (iv.) Water- and Food-Borne Diseases

This section begins by detailing the current level of water- and food-borne disease in the U.S. then asserts that climate change will increase the problem because increased temperature will spur the growth of the bacteria and virus that cause these diseases and increased precipitation will raise the risk of water contamination.

All of these diseases are preventable, and the techniques for their prevention well-known. If our current water and food handling systems were improved to the level necessary to prevent the current level of these diseases, they would be in good shape to prevent most, if not all, of the potential future occurrence of the diseases.

### (v.) Insect-, Tick-, and Rodent-borne Diseases

[40] Grazulis, T. P., 1993: Significant Tornadoes, 1680-1991. Environmental Films, St. Johnsbury, VT. 1326 pp.

This final section starts with the correct observation:

> "Diseases transmitted between humans by blood-feeding arthropods (insects, ticks and mites), such as plague, typhus, malaria, yellow fever and dengue fever were once common in the U.S. and Europe. … Many of these diseases are no longer present in the US, mainly because of changes in land use, agricultural methods, residential patterns, human behavior and vector control." [41]

The section then continues with a litany of why climate change could increase the risk of these diseases, before concluding:

> "A high standard of living and a well-developed public health infrastructure are central to the current capacity to adapt to the changing risks or vector- and rodent-borne diseases in the U.S. Maintaining and improving this infrastructure … remains a priority." [42]

However, this very reasonable statement is replaced by a statement of uncertainty in the USNA's Conclusions, which on the subject of vector-borne disease states:

> "… the Assessment team concluded that not enough is known about our adaptive capacity to say whether or not climate changes will make us more vulnerable to health problems. For example, while the ranges of potential disease-carriers such as mosquitoes are likely to expand, how society responds to this would largely determine whether or not disease outbreaks would actually occur."[43]

The authors of Chapter 15 were public health specialists who knew how to respond to the threat of increased vector-borne diseases, and gave us the information. Why isn't that information reflected in the Overview document?

### *e. Impact of Climate Change on El Nino and Hurricanes is Overstated*

Climate models predict changes in temperature, precipitation, cloudiness, and wind speed. The relationships between these parameters and climate impacts of interest, such as El Nino - Southern Oscillation (ENSO) and hurricanes, is a subject of intense scientific debate.

It is clearly beyond the scope of the USNA to make a complete assessment of the climate impacts literature, but a reasonable approach would be to indicate the range of estimates for each impact and the effect that would have on vulnerability. This was not done. Each chapter of the Assessment tended to make its own selection of the information available on potential impacts. In some cases this created a "worst case" approach, which might be

[41] USNA Draft, Chapter 15, Pg. 20.
[42] *Ibid.*, Pg. 22.
[43] *Ibid.*, Overview, Pg. 117.

justified under some circumstances, but only if clearly labeled as such. However, the USNA gives no indication that it is trying to portray a worst case.

### (i.) ENSO

The effects of projected changes in the El Nino - Southern Oscillation (ENSO) pattern appear in a number of places in the Assessment. Most chapters limit their discussion to the current effects of ENSO on the climate of their region or on their sector. However, a worst case projection of the impact of ENSO on future climate is presented in Chapter 5 on the Southeast, and Chapter 13 on Agriculture. Chapter 5 discusses the model projections indicating that increased atmospheric concentrations of greenhouse gases would lead to more frequent El Nino-like conditions and stronger La Ninas.[44] The effects of ENSO on agriculture in the U.S. are summarized as follows:

> "As climate warms, ENSO is likely to be affected. Models project that El Nino events and their impacts on US weather are likely to be more intense. There is also a chance that La Nina events and their impacts will be stronger. For this Assessment, the potential impacts of the changes in frequencies and strength of ENSO conditions on agriculture were modeled. An increase in these ENSO conditions is likely to cost US farmers an average of about $320 million per year if forecasts of these events are available and farmers use them to plan for the growing season and more if they do not." [45]

Neither Chapters 5 nor 11 indicate the intensity of the scientific debate on the question of whether climate change would lead to an intensification of ENSO.

To give some indication of the range of this debate, scientists who believe that ENSO is likely to be more intense include:

- Knutson and Manabe, who concluded that the predominance of El Nino conditions over the past two decades is "… not likely attributable to internal (natural) climate variability …"[46] ; and

- Trenberth and Hoar (1996), who, based on their analysis of the Darwin sea level pressure record, concluded that the 1990-95 ENSO event was "highly unlikely" to be due to "natural decadal-timescale variation." [47]

However, other researchers looking at the same information have come to the opposite conclusion.

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[44] USNA Draft, Chapter 5, Pg. 10.
[45] *Ibid.*, Chapter 13, Pg. 3 - 4.
[46] Knutson, T.R. and S. Manabe, 1998: Model assessment of decadal variability and trends on the tropical Pacific Ocean, *Journal of Climate*, **11**: 2273-2296.
[47] Trenberth, K.E. and T.J. Hoar, 1996. The 1990-1995 El Nino-Southern Oscillation Event: The longest on record. *Geophysical Research Letters*, **23**: 57-60.

- Harrison and Larkin concluded:

> "Taking into account the uncertainty in the number of degrees of freedom in the Darwin time series, we find that conditions like those of 1990 - 95 may be expected as often as every 150 - 200 years with 95% confidence." [48]

- Wunsch analyzed the sea level pressure record at Darwin, Australia, which is now considered by many researchers as a better long term indicator of El Nino conditions, and concluded:

> "… the Southern Oscillation … has long periods of apparent systematic signs and trends. Application of threshold-crossing statistics (Ricean) shows no contradiction to the assumption that the Darwin pressure record is statistically stationary." [49]

The inability to clearly identify a change in the frequency or intensity of ENSO events over the last century, during which both global average temperature and atmospheric $CO_2$ concentration rose, raises questions about model projections of future ENSO events. The models do suggest a more intense ENSO cycle, but given the variability of ENSO events, there is no evidence to suggest that the ENSO pattern will be statistically different in the future.

### (ii.) Hurricanes

Hurricanes, or more generally, tropical cyclones, affect three of the regions covered by the USNA: the Northeast, the Southeast, and the Caribbean and Pacific Islands. The treatment of the effect of projected climate change on hurricanes differs in the Overview document and in the three underlying three chapters:

- The Overview document states:

> "The projections are less certain regarding changes in the incidence of tropical storms and hurricanes, Some recent studies suggest that hurricanes will become more intense, while others project little change. It is possible that a 5 to 10% increase in hurricane wind speed will occur by 2100 … " [50]

- Chapter 5 on the Southeast mentions that El Nino conditions inhibiting tropical storm development in the Atlantic,[51] and that at least the Max Planck Institute climate

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[48] Harrison, D. E. and N. L. Larkin, 1997: Darwin sea level pressure, 1876 - 1996: Evidence for climate change?, *Geophysical Research. Letters,* **24**: 1779-82.
[49] Wunsch, C., 1999: "The interpretation of short climate records with comments in the North Atlantic and Southern Oscillations. *Bulletin of the American Meteorological Society*, **80**: 245-256.
[50] USNA Draft, Overview, Pg. 16.
[51] *Ibid.,* Chapter 5, Pg. 9.

model projects more El-Nino-like conditions[52], but does not put these two thoughts together to conclude there may be fewer hurricanes in the future.

- Chapter 11 on Caribbean and Pacific Islands also points out the role of El Nino in suppressing hurricane formation, and goes on to state: "Apart from the linkage with El Nino, it is not known how warming of global temperatures will affect hurricane or typhoon formation or dynamics."[53]

- The Key Findings of Chapter 4 on the Northeast warn: " Potential changes in the intensity and frequency of hurricanes are a major concern."[54]

Chapter 4's conclusion is surprising, not only because of the information in Chapters 5 and 11, but also because of the text in Chapter 4 itself, which reads:

> "Given the spatial resolution of global climate models, neither thunderstorm nor hurricanes are simulated by the models. An analysis of sea level pressure patterns in the Hadley and Canadian models, which provides some indication of the path of hurricanes if they form, suggest little reason to expect changes in the average track of hurricanes over the next century. Changes in frequency and intensity of hurricanes under future climate conditions remains a topic of considerable debate." [55]

Hurricanes and other forms of severe weather do great damage under current conditions, but the case cannot be made that the situation would be worse in the future, even under the extreme climate change conditions the USNA projects.

### *f. Attributing Impacts Due to On-going Trends to Climate Change*

The Assessment attributes a number of impacts which are the result of ongoing trends to climate change. Examples of this range from the significant to the minor.

The key findings in the Overview Report reads:

> "At the national level, the agriculture sector is likely to be able to adapt to climate change. Overall, US crop productivity is very likely to increase over the next few decades, but gains will not be uniform across the country." [56]

This sounds like good news, but then is tempered by the following statement: "Falling prices and competitive pressures are very likely to stress some farmers."[57] The Summary of Chapter 13, Climate Change and Agriculture in the United States, is more explicit:

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[52] *Ibid.*, Pg. 10.
[53] *Ibid.*, Chapter 11, Pg. 15.
[54] *Ibid.*, Chapter 4, Pg. 3.
[55] *Ibid.*, Pg. 9.
[56] *Ibid*., Overview, Pg. 7.
[57] *Ibid.*

"Under climate change, consumers will likely benefit from lower prices while producers will likely see their profits decline."[58]

Prices for agricultural commodities have been declining for decades, and can reasonably be expected to continue to decline in the future, independent of potential climate change. The economic changes detailed in Chapter 13 are relatively small, and no comparison is made between the impacts of potential climate change and other factors affecting agricultural economics. The reader is left with the incorrect impression that climate change is the only factor that will affect the profitability of agriculture. Also, despite widespread discussion of the cultivation of biomass as an energy resource, there is not discussion of this potential option as an off-set to any decline in the profitability of food production.

In addition, the USNA does not take adaptation options fully into account. When this is done, as it has been in other studies, the result for the U.S. agricultural sector is positive. Mendelsohn and Neumann report on economic analyses that consider the impact on the agricultural sector in 2060 of a wide range of temperature (1.5 - 5$^{o}$ C or 2.7 - 9$^{o}$ F) and precipitation (0 - 15%) increases taking adaptation fully into account. They conclude that the result in positive in every case, with the benefit ranging from $9.5 billion - $53.5 billion (1990$).[59] While Mendelsohn and Neumann do not address the specific concern raised in the USNA about some farmers who might be stressed by lower prices, they conclude that there is an overall benefit to the economy.

In a more minor, but equally incorrect example, consider the emphasis placed on the displacement of the New England sugar maple industry into Canada. It is mentioned in the Overview Report as part of key findings,[60] in the key findings of Chapter 4,[61] and is the subject of a whole page of discussion in Chapter 4.[62] However, it is only when one reads this detailed discussion that the following information is provided: "It is interesting to note that in 1928, the major syrup production center in the US was located in Garrett County, Maryland." This would seem to indicate that the northward shift of the sugar maple industry has been underway for more than 70 years and is likely to continue independent of the climate change scenarios presented in the Assessment.

### *g. Cursory and Inadequate Treatment of Adaptation*

The introduction to the Assessment Overview claims that the U.S. National Assessment process claims:

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[58] *Ibid.*, Chapter 13, Pg. 2.
[59] Mendelsohn, R. and J. E. Neumann, 1999. *The Impact of Climate Change on the United States Economy.* Cambridge University Press, Pg. 316.
[60] *Ibid.*, Overview, Pg. 7.
[61] *Ibid*., Chapter 4, Pg. 3.
[62] *Ibid.*, Pg. 26.

> "… has sought to identify key climate vulnerabilities in particular regions and sectors, in the context of other changes in the nation's environment, resources and economy. It has also sought to identify potential measures to adapt to climate variability and change." [63]

However, these two aspects of the process, vulnerabilities and adaptation, are presented in a separate, and very unequal, fashion. In the Overview document, adaptation is first discussed on page 32, then only in general terms. No information is provided on the strategies for adaptation, nor on the extent to which adaptation strategies might offset the potential impacts of climate change. Also, there is no mention of the value of adaptation strategies in providing protection against current climate variability.

The same approach is used in the chapters of the Foundation document. For example, Chapter 4 on the Northeast devotes only one page out of roughly 30 pages of text to adaptation strategies, does not give any indication of the degree to which they might offset the potential impacts of climate change, or mention them as part of the chapter findings.

This shortcoming of the Assessment is acknowledged, but not very visibly, in Chapter 3, Socioeconomic Context for Climate Change Assessment:

> "In this first Assessment, potential climate adaptation options were identified, but their feasibility, costs, effectiveness, or the likelihood of their actual implementation were not assessed. Careful assessment of these will be needed." [64]

It is well recognized that adaptation measures can greatly reduce the impacts and cost of climate change. Presenting a detailed assessment of U.S. vulnerabilities to climate change, without an equally detailed assessment of what the U. S. can do to adapt to climate change, is both misleading and irresponsible.

Rather than claiming that it is treating adaptation in the same fashion that it is treating vulnerability, the USNA should redefine its goal as an examination of vulnerability, acknowledge that it presents only a cursory identification of potential adaptation options, and stress the critical importance of further evaluation of these options.

[63] *Ibid.*, Overview, Pg. 2, "About the Assessment Process"
[64] *Ibid*., Chapter 3, Pg. 8.

## 5. Impact of Capability Limitations on the Quality of the U.S. National Assessment

Critical issues of climate science and U.S. research capability were clearly spelled out in the National Research Council (NRC) report on *Global Environmental Change: Research Pathways for the Next Decade.* Comparison of this NRC study and the U.S. National Assessment points toward a number of serious compromises made in the National Assessment effort and highlights two critical concerns NRC raised about U.S. research capabilities – climate models and socioeconomic modeling.

### *a. Climate Models*

The USNA acknowledges that the use of only two climate models "provides a limited opportunity to investigate the consequences of climate variability and change." They also refer to this as "the minimum strategy approach". [65]

The minimum strategy approach is even clearer when one considers that the USNA used existing model runs to carry out its study. The USNA describes its choice of model results as follows:

> “In the selection of the particular set of model results to be used for the assessment, a number of additional constraints were also considered. For example, time and computer resource constraints generally prevented the completion of a new set of model simulations with these models specifically designed for this assessment. … limitations in capabilities and resources have meant that the set of cases and situations that all teams would be asked to use needed to be kept to a minimum.” [66]

Since a 1% per year increase in $CO_2$ emissions is the simulation that has been most frequently run on climate models, these "time and computer resource constraints" locked the USNA into an unrealistic emissions scenario.

The USNA's discussion of "down-scaling", i.e., regional climate modeling, states:

> “These models (regional climate models) are able to represent important processes and mountain ranges on a finer scale than do GCMs. However, these simulations are very computer intensive and (it) has not yet been possible to apply the techniques nationally or for the entire 21st century.” [67]

[65] USNA Draft, Chapter 1, Pg. 33, lines 30 - 40.
[66] *Ibid.*, Pg. 30, lines 25 - 34.
[67] *Ibid.*, Pg. 34, lines 21 - 23.

However, the Hadley Centre, the developers of one of the regional modeling approaches claims that the approach can be used for domains as large as 5000 km square, an area larger than the contiguous 48 states.[68]

The USNA's approach is understandable when one considers the following NRC critique of U.S. climate modeling capabilities:

> "The policy issues that confront global change research … are serious, particularly with regard to their impact on humans. These issues rely on models of exceedingly complex behaviors over a significant range of scales in space and time. Significant challenges face the scientific community in the form of many and various modeling issues, from initialization to validation. Important, unsolved, and difficult problems remain for formulating useful prognostic models over a range of topics in human dimensions research. Advances in developing *and most importantly in testing and evaluating models* are needed. **The United States is no longer in the lead in this critical field.** (emphasis in original)
>
> "… Currently, the potential exists that the advanced models built in the United States cannot (or will not) be adequately tested and properly applied to key problems, such as national and regional expressions of transient climate variability and change because of lack of available computing resources. The United States must apply greater resources, particularly (but not exclusively) in the area of advanced computing machines. National boundaries should not influence where machines are purchased.
>
> "… there must be a considerably expanded commitment of resources to modeling, especially at the temporal and spatial scales needed by the policy community." [69]

The USNA depended on existing climate model runs from the UK and Canada, even though they used an unrealistic emissions scenario, because they were superior to what could be made available by U.S. researchers. The USNA did not use regional climate modeling because it did not have access to either the models or the computers on which to run them.

### *b. Socioeconomic Modeling*

The USNA lays out the need for socioeconomic modeling as follows:

> "… the impacts of climate change that matter to people are not limited to direct biophysical impacts, but can also include many indirect effects, such as health

[68] Jenkins, G., *et al.*, 2000: "Regional Climate Predictions for National Vulnerability Assessments: Capacity Building in Developing Countries", Hadley Centre for Climate Prediction and Research, Pg. 3.
[69] NRC, 1999: Global Environmental Change: Research Pathways for the Next Decade. pg. 532 - 533.

> effects, changes in income and employment … Such impacts are not exclusively caused by weather or climate, but are mediated by many characteristics of the economy and the society. … Climate conditions and societal conditions jointly cause climate impacts." [70]

Having defined the need for socioeconomic modeling, the USNA then defines the standard for such modeling.

> "The central place of socioeconomic conditions in determining impacts requires that they be considered, and for many analyses be explicitly projected. But the profound limits to our knowledge of the factors that determine socioeconomic change requires that explicit acknowledgement of uncertainty be central to such projections. This requirement cannot be met by assuming any single socioeconomic future. Rather, there should be multiple scenarios representing a plausible range (of) alternative socioeconomic futures, ideally with explicit quantifications of uncertainty judgements, and the sensitivity of results to alternative assumptions should be examined." [71]

Having defined this requirement, the USNA proceeded to ignore it. The socioeconomic procedure they used is described as follows:

> "A working group of the NAST (National Assessment Study Team) was charged with developing scenarios for the socioeconomic assumptions necessary for the assessment. Because of the complexity and diversity of the socioeconomic characteristics that might be important contributors to impacts and vulnerability, and because of the highly decentralized nature of the National Assessment process, this working group judged it infeasible to attempt to develop fully detailed socioeconomic scenarios centrally. … Rather the working group attempted to balance the assessment's competing needs for reflecting regional concerns and expertise, while maintaining enough consistency to allow national-level synthesis, by recommending a two-track approach to scenario development, partly centralized and partly decentralized.
>
> "The centralized track comprised a few key socioeconomic variables likely to influence many domains of impact, such as population, economic output, and employment. For these, where nationwide consistency was most important, the working group developed three internally consistent socioeconomic scenarios, which were used in all region and sector studies….
>
> "The decentralized track was to be used when a particular analysis required future values of more specific or local socioeconomic characteristics to be defined. In this case, the relevant assessment team was asked to develop and document the required assumptions themselves." [72]

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[70] USNA Draft, Chapter 3, Pg. 3, lines 29 - 42.
[71] *Ibid.*, Pg. 4, lines 12 - 18.
[72] *Ibid.*, Chapter 3, Pg. 9, line 20 - Pg. 10, line 1.

Defining "a few key socioeconomic variables" is not the same as defining "a plausible range of alternative socioeconomic futures". No attempt was made to provide "explicit quantifications of uncertainty judgements, and the sensitivity of results to alternative assumptions." As a result, none of the key findings reported in the Overview discuss different levels of impacts or concerns based on differences in socioeconomic assumptions.

As is the case with climate modeling, the U.S. is incapable of conducting the socioeconomic modeling necessary for an effort such as the USNA because it has not supported the research needed to build this capability. In 1999, the NRC described the situation as follows:

> "As outlined in the USGCRP's (1997) *Our Changing Planet*, human dimensions research should be a component of each science theme as well as a cross-cutting issue. What is needed now is to organize the USGCRP so as to make this a reality. … Some steps are currently being taken towards such integration … Such efforts need to be encouraged and their research recommendations implemented.
>
> "[However,] [s]tructuring support for human dimensions research only around themes defined by the natural science is inadequate because certain human dimensions issues cut across all of the research themes and require cross-cutting and independent research initiatives. These initiatives include those on valuing environmental quality, the problem of developing improved methods for environmental decision making, and some questions about the human driving forces of environmental change. The challenge of organizing research on these crosscutting issues is confounded by multi-agency responsibilities for funding. … NSF, the agency responsible for the largest share of designated human dimensions research funding within USGCRP, is the agency with the most experience in engaging basic social, behavioral, and economic science expertise and in providing a strong peer review system for proposals. However, NSF funds primarily investigator-initiated and disciplinary, rather than problem-oriented and interdisciplinary, social science research. …
>
> "Basic social science research on human dimensions administered by disciplinary programs at NSF in response to investigator-initiated proposals is very important. But support is also needed in the form of interdisciplinary review panels, interagency collaboration, and research driven by specific science plans and organized in centers of excellence to advance human dimensions research." [73]

The interdisciplinary socioeconomic research called for by the NRC is exactly what USNA needed for its socioeconomic evaluation. Such research was not available in the U.S., but was being developed elsewhere and was used extensively by the

[73] NRC, 1999: Global Environmental Change: Research Pathways for the Next Decade, Pg. 353 - 355.

Intergovernmental Panel on Climate Change (IPCC) in developing its Special Report on Emissions Scenarios.